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Project Summary

Survey and Evaluation of Fine Bubble Dome Diffuser Aeration Equipment

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This research project was initiated with the overall objective of better defining the oxygen transfer performance, operation and maintenance requirements, and proper design approaches for fine bubble dome *diffuser aeration systems* used in activated sludge wastewater treatment.

Working with the British Water Research Centre of Stevenage, England, the Association of Metropolitan Sewerage Agencies surveyed 19 wastewater treatment plants with dome diffuser aeration equipment and reviewed the related literature. Thirteen of the plants were in the United Kingdom, two in The Netherlands, and four in the United States. The U.K. plants were selected primarily on the basis of long-term experience (5 yr or longer) and were all municipal wastewater treatment plants with varying industrial flows. The Netherlands and U.S. plants were chosen on the basis of availability rather than longevity.

As nearly as possible, data on influent and effluent wastewater characteristics, power demand, air supply, and process parameters were compiled for a 5-yr period. Maintenance personnel were interviewed to develop a summary of long-term operation and maintenance (O&M) experience. Specific designs and plant equipment for aeration, air cleaning, and diffuser maintenance were studied. Discussions were held with designers, equipment manufacturers, and research scientists to develop a better understanding of design and performance.

Although this survey clearly shows the need for optimized design and operating control strategies to realize the full energy saving potential of this type of equipment, dome diffuser fine bubble aeration systems were providing relatively efficient, low-maintenance service in the plants visited.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that are fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

As with other energy-intensive industries, energy-conserving design and operation is receiving increased emphasis in the wastewater treatment field. Aeration equipment employed in activated sludge service is usually the single largest energy consumer in a wastewater treatment plant, normally accounting for 60 to 80 percent of total power demand. Because fine bubble aeration equipment has the potential for markedly higher oxygen transfer efficiencies than the more traditional coarse bubble spiral roll design, its use is rapidly expanding in new or retrofitted treatment plants.

Historically, fine bubble aeration equipment was widely used in the United States before 1950. It gradually fell into disfavor because of its fairly intensive maintenance requirements and was replaced by the very low maintenance coarse bubble equipment during the period of relatively cheap power prior to 1972. Rapid escalation in U.S. power costs since the 1974 Arab oil embargo has renewed interest in fine bubble aeration.

Because power costs have traditionally been much higher in the United Kingdom and Western Europe than in the United States, fine bubble aeration equipment, along with mechanical surface aerators, continued to be widely used and improved there. The ceramic dome diffuser, which is the main subject of this study, was first developed in 1954 and refined into its present form by 1961. In 1972, it became available in the United States under a licensing agreement. Although there are presently only a handful of U.S. installations, the dome diffuser is in use in several hundred treatment plants around the world and the last few years have seen the evolution of competing devices in either dome or disc form.

The purpose of this study was to assess the long-term oxygen transfer performance and O&M history of dome diffuser aerators. A total of 19 treatment plants were studied—13 in the United Kingdom because of the large number of major municipal treatment works with 5 yr or greater operating experience in that country. The British Water Research Centre (WRC) cooperated in the U.K. study and was able to add substantially to the data base. Two plants in The Netherlands were studied, and the considerable Dutch research effort on the various types of dome/disc diffuser aerators was reviewed. Four plants were visited in the United States; three of these were running side-by-side comparisons with other types of aeration equipment. A literature review was carried out in conjunction with the WRC and EPA. A corollary activity in this project was a review of the process design of dome diffuser aeration systems and the formulation of design recommendations.

General Design Characteristics of Surveyed Plants

Most of the visited plants had aeration systems of the plug flow configuration, using long, narrow channels with one or more passes. Several used step feeding for better load distribution. All of the surveyed plants were equipped with dome diffusers manufactured by Norton/Hawker-Siddeley.* Most of the plants in the United Kingdom produced fully nitrified effluents of high quality; several practiced denitrification as well. A list of the surveyed plants and background data are provided in Table 1.

Aeration Systems

Aeration systems design data for the surveyed plants are summarized in Table 2. Average process performance data for 1978-79 are presented in Table 3.

Plug flow aeration systems were in use at all of the plants visited. Approximately one-half of the plants had two or more passes per aeration tank. The majority of the plants were operated in the full plug flow mode with effective length-to-width ratios up to 106 when multiple passes were considered. The U.K. plants exhibited very conservative design approaches, owing principally to very stringent discharge requirements. Only three U.K. plants did not fully nitrify. Most achieved treatment levels exceeding 95 percent removal of BOD_5, suspended solids, and ammonia nitrogen. Food-to-microorganism (F/M) loadings in U.K. plants typically ranged from 0.1 to 0.2 kg BOD_5/day/kg mixed liquor suspended solids (MLSS), and volumetric loadings ranged from 0.16 to 0.40 kg BOD_5/day/m^3 (10 to 25 lb/day/1000 ft^3) except in the higher rate plants or those receiving strong industrial wastes. Similarly, the nitrifying U.K. plants consumed two to three times more air per unit of BOD_5 removed than did the conventional activated sludge, non-nitrifying, U.S. plants. Because volumetric loading rates were lower, however, air flow rates per unit volume of aeration tank were similar to those in U.S. plants. Diffuser density and air flow rates per diffuser were also quite similar; this reflects the commonality of dome diffuser aeration design in both countries. Tapered aeration, full or partial, was used in all but four of the 19 plants surveyed.

Mixing power levels at minimum air flow rates were relatively low in most of the plants. Only one plant, Minworth, reported any deposition of mixed liquor solids; that occurred in the lightly mixed anoxic zone. Significantly, all of the lightly mixed plants had very effective primary sedimentation. MLSS at all of the plants except Oxford were less than 3500 mg/l. Oxford compensates for higher-than-average volumetric loadings by carrying 4500-5000 mg/l MLSS, maintaining low F/M loadings to promote nitrification. The range of power levels given reflects the practice of tapered aeration, whereby air input (and hence power input) is front loaded in the plug flow plants. Often, mixing in the lightly aerated section of plug flow plants with tapered aeration was enhanced by central placement of the diffusers, along the tank length axis, carrying a double spiral mixing pattern.

Prevention of Denitrification in Final Clarifiers.

Single-stage nitrification (BOD removal and nitrification in the same tank) was being achieved in most of the U.K. plants surveyed. To combat denitrification in the final clarifiers, four plants have been experimenting with partial denitrification using anoxic zones in the front ends of their respective aeration tank batteries.

Experimental denitrification studies have been conducted at Rye Meads by the WRC and the Thames Water Authority. It was determined that 50 percent removal of nitrate nitrogen was the practical upper limit of the process as used at Rye Meads. Parallel laboratory studies suggested that the degree of denitrification might be increased another 10 to 20 percent by adding a second anoxic zone at the beginning of the third pass at Rye Meads. This has not been fully supported by the experimental results at Rye Meads.

Process modifications have been undertaken at Coleshill to optimize overall activated sludge performance and reduce settling problems in the final clarifiers caused by denitrification. In the period June-December 1978, nitrate removal through the process (including that occurring in final clarifiers) ranged from 42 to 57 percent. Dramatic improvement in the problem of rising sludge in the clarifiers was reported. A change in the clarifier desludging schedule, decreasing detention time during low flow periods, also helped alleviate the problem.

Oxygen Transfer Performance

Method of Analyzing Oxygen Transfer Efficiency

Currently, there are many methods for measuring oxygen transfer efficiency, including steady and nonsteady state

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*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Table 1. *Surveyed Plant Characteristics*

Plant Location/Name	*Aeration System Description*	*1978/1979 Average Flow*		*Average Performance*		*O & M Experience**
		mgd	*m^3/sec*	*%$(BOD_5)_R$*	*%TSS_R*	
United Kingdom						
Basingstoke	*Nitrifying, 1-pass plug flow, symmetrical aeration*	4.9	0.22	97	97	A
Beckton (New Plant)	*Nitrifying, 1-pass plug flow, tapered aeration*	174	7.6	95	94	+
Beddington	*Nitrifying, 2-pass plug flow, tapered aeration*	25.5	1.12	96	97	–
Long Reach	*Non-nitrifying, 4-pass plug flow, tapered aeration*	52.8	2.31	94	91	+
Mogden (Battery B)	*Nitrifying, 4-pass plug flow, some aeration taper*	45.2	1.98	97	97	+
Oxford (1969 Plant)	*Nitri/denit, 1-pass plug flow, tapered aeration*	5.3	0.23	98	96	+
Rye Meads (Stage III)	*Nitri/denit, 4-pass plug flow, tapered aeration*	10.4	0.46	98	98	+
Coalport	*Nitrifying, 2-pass step feed, symmetrical aeration*	3.2	0.14	95	95	+
Coleshill (Stage III)	*Nitri/denit, 1-pass plug flow, tapered aeration*	13.5	0.59	96	96	+
Finham (South)	*Non-nitrifying, 1-pass plug flow, symmetrical aeration*	7.5	0.33	90	92	+
Hartshill	*Non-nitrifying, 1-pass plug flow, tapered aeration*	5.7	0.25	94	94	+
Minworth	*Nitri/denit, 1-pass plug flow, tapered aeration*	72.4	3.17	96	96	+
Strongford (New Plant)	*Nitrifying, 1-pass plug flow, some aeration taper*	10.6	0.46	95	--	+
The Netherlands						
Holten-Markelo	*Nitri/denit, 2-pass plug flow, tapered aeration*	4.7	0.21	93	92	+
Steenwijk	*Nitrifying, 2-pass plug flow, tapered aeration*	11.8	0.52	96	95	+
United States						
Glendale, Calif.	*Non-nitrifying, 1-pass plug flow, tapered aeration*	3.0†	0.13†	90	90	+
Madison, Wisc.	*Non-nitrifying, 3-pass step feed, tapered aeration*	14.5	0.64	88	92	+
Fort Worth, Tex.	*Non-nitrifying, 1-pass plug flow, tapered aeration*	99‡	4.3‡	--	--	–
Tallman Island, N.Y.	*Non-nitrifying, 2-pass plug flow, step feed*	68	2.98	86	--	+

**A = average; B = better than average; – = worse than average.*
†10-mo data.
‡3-mo data.

procedures. For this study, oxygen transfer efficiency was estimated using a mass balance technique based on empirically derived oxygen consumption values for BOD_5 removed and ammonia nitrogen oxidized and on a similarly derived oxygen credit for nitrate nitrogen denitrified. The method was developed by Boon and Hoyland of the WRC based on the work of Eckenfelder and has an estimated ± 20 percent accuracy.

The oxygen mass balance technique used in this project is represented by the following equation:

$$G_t = 10^{-3}f[R(B_s-B_e) + 1.64(N_s-N_e) + 2.83N_e^*]$$

where: G_t = overall rate of oxygen consumption by microorganisms in an aeration tank, kg/sec
f = average wastewater flow rate, m^3/sec
B_s = primary effluent BOD_5, mg/l
B_e = final effluent BOD_5 mg/l
N_s = primary effluent NH_4^+-N, mg/l
N_e = final effluent NH_4^+-N, mg/l
N_e^* = final effluent NO_3^--N, mg/l
R = $0.75 + 0.05/(F/M)$, for $0.1 \leq F/M \leq 0.5$ where $F/M = (B_s-B_e)/(MLSS \times T)$
MLSS = concentration of suspended solids in aeration tank, mg/l
T = wastewater detention time, days

Results of Plant Surveys

Table 4 summarizes the oxygen transfer performance estimates developed as a result of the plant surveys. Oxygen transfer performance is typically expressed in terms of aeration efficiency, which is defined as the mass transfer of oxygen per unit of line, or wire, power input. The values of aeration efficiency (Table 4) for the various plants were estimated using the oxygen mass balance methodology previously described.

A wide range of performance levels are apparently occurring at the dome diffuser plants surveyed, even where process conditions are seemingly similar. Plants with long-term performance

Table 2. *Aeration System Design Data*

Plant Location/Name	Aeration Basin Dimensions Lgth (m)*	Wdth (m)*	Dpth (m)*	L/W	Diffuser Density (domes/m^2)†	Aeration Taper (%)	Minimum Mixing Power Level (W/m‡	Avg. Air Flow/ Min. Air Flow
United Kingdom								
Basingstoke	79.2	6.7	2.5	12	3.9	none	20.8	1.5
Beckton (New Plant)	223	41.2	3.1	5.4	2.8-1.9	46/31/23	13.6-6.8	1.5
Beddington (New Tanks)	67	7.3	2.4	18.4	2.7-1.1	34/28/23/15	16.1-6.4	1.8
Long Reach	80	6.0	3.8	53	7.8-3.5	35/27/23/15	58.7-25.7	2.0
Mogden (Battery B)	122	4.6	3.7	106	5.0-3.1	34/22/22/22	29-18.5	1.0
Oxford (1969 Plant)	37.8	6.9	2.4	5.5	3.8	43/28	18.8	1.5
Rye Meads (Stage III)	70	4.3	3.0	65	4.6-2.3	21/33/28/18	29-13.8	2.4
Coalport	65	4.6	4.3	27.8	2.8	none	25-16.7	1.2
Coleshill (Stage III)	64	18.3	2.9	3.5	3.9-2.0	§	36.9-16.7	2.0
Finham (South)	61	3.0	3.6	20.3	4.3	none	36.0	1.5
Hartshill	27.4	9.2	3.2	3.0	5.9-4.1	59/41	89.0-62.0	--
Minworth	178	18.3	3.0	9.7	0.4/1.9-0.9	§	26.8-13.4	1.25
Strongford (New Plant)	108	9.3	3.0	46.4	2.3-1.9	§	--	--
The Netherlands								
Holten-Markelo	30	6.6	4.0	9.1	1.9-0.9	34/25/25/16	--	--
Steenwijk	100	6.75	4.0	29.6	2.8-1.5	34/25/25/16	20-10	--
United States								
Glendale, Calif.	73.2	9.75	4.9	7.5	3.0-0.9	57/43	24-7.5	1.4
Madison, Wisc.	41.2	9.1	4.7	13.6	9.1-3.6	48/29/23	33.7-13.4	1.5
Fort Worth, Tex.	83.8	36.6	4.3	23	5.4-3.0	34/27/21/18	--	1.4
Tallman Island, N.Y.	110	28	4.9	7.9	1.3	none	--	1.2

*1 m = 3.28 ft.

†1 dome/m^2 = 9.29 domes/100 ft^2.

‡1 W/m^3 = 0.038 wire hp/1000 ft^3.

§See Appendix B of main report.

Table 3. *Aeration Process Performance Data*

Plant Name/Location	Average Flow & Data Year (m^3/sec)*	Design DWF (m^3/sec)*	BOD_5 (mg/l) Raw	Primary	Effluent	Volumetric Loading (lb BOD_5/day/ 1000 ft^3)†	F/M Loading (kg BOD_5/day/kg^2)	Average Air Flow ft^3/lb BOD_5‡	cfm/1000 ft^3§	Remarks
United Kingdom										
Basingstoke	0.22/78-79	0.26	281	157	4	22.4	0.08	1910	28.9	
Beckton (New Plant)	7.6/78-79	8.8	169	96	8	20.6	0.13	1110	16.8	Non-nitrifying
Beddington (New Tanks)	1.12-78-79	0.96	320	149	12	11.7	0.20	1785	13.4	
Long Reach	2.31/78-79	1 97	334	180	20	44.0	0.30	612	16.6	Non-nitrifying
Mogden (Battery B)	1.98/78-79	1.53	238	99	8	9.8	0 18	1392	20 8	
Oxford (1969 Plant)	0.23/78-79	0.17	367	165	7	41.0	0.10	1046	26.2	Initial anoxic zone
Rye Meads (Stage III)	0.45/78-79	0.42	310	144	5	24.3	0.08	1416	23.0	Initial anoxic zone
Coalport	0 14/78-79	0.20	--	157	9	36.0	0.14	1402	11.0	
Coleshill (Stage III)	0.42/78-79	0 62	--	158	12	22.9	0.10	1000	15.8	Initial anoxic zone
Finham (South)	0.32/1979	0.26	321	162	32	70.0	0.45	693	34.4	High rate, non-nitrifying
Hartshill	0.25/1979	0.28	500-700	400-500	20-40	112	0.30	747	43.8	1 mo data
Minworth	3.17/1978	2.11	--	142	6	22.2	0.09	689	10.1	Initial anoxic zone
Strongford (New Plant)	0.47/1979	0.77	250	50-100	10	--	0.05	--	--	Figures approx.
The Netherlands										
Holten-Markelo	0.21/1978	0.15	400	182	21	30.4	0.18	--	--	Non-nitrifying
Steenwijk	0.52/1978	0.62	312	102	12	24.2	0.11	--	--	Partial nitrification
United States										
Glendale, Calif.	0.13/78-79	--	220	158	11	31.9	0.35	748	15.4	Non-nitrifying
Madison, Wisc.	0.63/1979	--	213	156	19	27.0	0.30	732	80.0	Non-nitrifying
Fort Worth, Tex.	4.3/pt. 1979	4.2	--	--	--	--	--	--	--	Non-nitrifying
Tallman Island, NY	3.0/78-79	3.5	91	64	13	29.6	0.24	--	--	Non-nitrifying

*1m^3/sec = 22.8 mgd.

†1 lb/day/1000 ft^3 = 0.016 m^3/day/m^2.

‡1 ft^3/lb = 0.062 m^3/kg.

§1 cfm/1000 ft^3 = 0.017 1/m^3/sec.

Table 4. *Oxygen Transfer Performance Data Summary*

			Percent Saturation of Mixed Liquor D.O.		*Aeration Efficiency**				*Years*
Plant	*Aeration Tank L/W*	*MLSS (mg/l)*	*Range*	*Average*	*High (kg/kWh)*	*Low (kg/kWh)*	*Average (kg/kWh)*	*Average (lb/hp-hr)*	*of Data*
Beckton	*5.4*	*2900*	*10-80*	*40*	*1.95*	*1.54*	*1.75*	*2.88*	*3*
Basingstoke	*12*	*4900*	*10-60*	*30*	*1.20*	*1.08*	*1.16*	*1.91*	*5*
Mogden	*106*	*2300*	*10-100*	*50*	*1.62*	*1.12*	*1.37*	*2.25*	*5*
Oxford	*5.5*	*5500*	*10-40*	*20*	*2.34*	*1.93*	*2.13*	*3.50*	*5*
Rye Meads	*65*	*4700*	*20-100*	*60*	*1.14*	*1.04*	*1.09*	*1.79*	*3*
Coalport	*27.8*	*2500*	--	--	--	--	*1.08*	*1.78*	*1*
Coleshill	*3.5*	*3000*	*20-50*	*35*	--	--	*2.12*	*3.49*	*1*
Minworth	*9.7*	*3200*	--	--	--	--	*1.71*	*2.81*	*1*
Strongford	*46.4*	*5000*	*20-100*	*80*	--	--	*1.49*	*2.45*	*1 wk*
Beddington	*18.4*	*2300*	--	*15*	*1.25*	*1.05*	*1.11*	*1.83*	*10*
Hartshill	*3.0*	*3000*	*reported low*	--	--	--	*1.11*	*1.83*	*1 mo*
Long Reach	*53*	*1700*	*10-40*	*20*	--	--	*2.07*	*3.40*	*1*
Finham	*20.3*	*2000*	--	--	--	--	*1.76*	*2.89*	*1*
Steenwijk	*29.6*	*3300*	--	--	--	--	*0.78*	*1.28*	*1*
Glendale	*7.5*	*2000*	*10-30*	*20*	--	--	*1.14*	*1.87*	*10 mo*
Madison	*13.6*	*2000*	*10-30*	*20*	*1.99*	*1.56*	*1.77*	*2.91*	*2*
						Average:	*1.48*	*2.43*	

**Defined as mass of* O_2 transferred per unit of power input as measured by the line draw.

data, such as Beddington, exhibit fairly constant performance data over the period of record. The two U.S. plants for which performance could be estimated seem to be similar in both process design and performance. The Dutch plants are more closely related to U.S. plants in design; however, the estimated performance at Steenwijk is somewhat less for unknown reasons.

Operation and Maintenance

General Maintenance Experience

Maintenance observations at the 19 survey plants are summarized (Table 5). Generally, the plants have had good, and often exceptional, reliability from dome diffuser equipment. After initial shakedown, the plastic pipe mounted systems have performed well. Earlier plants used dome diffusers mounted on a cast iron air distribution grid. Rusting of the interior surfaces of the air lines led to rust and scale deposits on the interiors of the domes and caused plugging after 5 to 6 yr. Most of the plants with iron pipe are retrofitting to plastic pipe with generally good results. Several of the retrofitted plants have experienced minor problems with some of the anchors that hold the plastic pipe saddles to the tank floor coming loose and pulling out. The cause of this seems to be spalling of concrete around the mounting holes in the floors. This has not been reported as a problem in systems where tank concrete is new and apparently less vulnerable to spalling.

Several plants have also reported scattered failures of other plastic parts, notably the pipe coupling straps and orifice bolts. Beckton had major problems on startup with the coupling straps. Mogden has had considerable problems with failure of the orifice bolts, probably related to over tightening during installation. Most of the plants, however, reported few or no startup problems of this nature. Careful supervision of installation to avoid overtightening of plastic parts was cited as the key to trouble free startup by most of the plant personnel. It was also noted that the plastic parts were much less costly to replace than the previously used brass bolts.

Formation of Biological Slimes on Diffusers

The major operational problem associated with the dome diffusers was the formation of biological slimes on diffusers operating in zones of high volumetric loading and/or low dissolved oxygen (D.O.). Beddington continues to have major problems with slime formation, which manifests itself as coarse bubbling at the surface of the aeration tank. The slime growth does not cause an increase in air pressure; rather, it induces an apparently wholly external surface fouling that causes the air bubbles to coalesce after exiting the surface of the diffuser domes. The resulting coarse bubbling lowers oxygen transfer efficiency, thereby lowering mixed liquor D.O. and further encouraging slime growth.

When first confronted with the problem, Beddington removed and refired their fouled domes. On startup of a cleaned tank, the problem quickly recurred, however, and it was soon obvious that other, less costly solutions were needed. In further tests, a vigorous brushing of the dome surface accompanied by high air flow rates was found to return the dome to nearly new performance levels. Periodic tank cleaning and dome brushing have allowed Beddington to control (not eliminate) the problem at moderate cost.

Although Beddington's sliming problem was intensified by the presence of strong industrial wastes, which depressed oxygen transfer efficiency and caused low D.O. in the first passes of the multi-pass plug flow tanks, it was not the only plant that exhibited sliming. Indeed, every plant visited showed some signs of coarse bubbling, which was probably attributable to slime growth on domes. Without exception, the phenomenon occurred at the primary effluent feed points or at the transition from anoxic to aerobic treatment. It was particularly severe in the first 20 to 25 percent of the first pass of two-to-four-pass plug flow systems. Tapering the aeration helped somewhat but did not fully solve the problem.

Table 5. *Maintenance Data Summary*

Plant Name/Location	*Started Up*	*Startup Experience*	*Cleaned*	*Operating Experience*
United Kingdom				
Basingstoke	*1964-71*	*Some problems with plastic tank bottom mounts*	*Every 5 yr*	*Fair, scale problems*
Beckton				
New Plant	*1970*	*Problems with plastic holddowns*	*Every 8 yr*	*Good after initial problems*
Old Plant	*1959*	*No significant problems*	*Twice in 15 yr*	*Gradual plugging due to rust in cast iron pipes*
Beddington (New Tanks)	*1969*	*No significant problems*	*Every 4 yr**	*Poor but improving major slime problem*
Long Reach	*1978*	*No significant problems*	*Not yet*	*Good, new plant*
Mogden (Battery B)	*1961*	*No significant problems*	*Every 6 yr*	*Plastic retrofit in Battery B (1968) has not yet required cleaning*
Oxford	*1969*	*Some problems with plastic tank bottom mounts*	*Not yet*	*Good, no apparent loss of effluent quality after 10 yr*
Rye Meads	*1956-70*	*Some problems with retrofitted plastic piping*	*Every 6 yr*	*Fair, plugging due to rust in older lines. Plastic system good*
Coalport	*1970*	*No significant problems*	*Not yet*	*Good*
Coleshill (Stage III)	*1968*	*No significant problems*	*Not yet*	*Good, tanks cleaned once/year and domes brushed*
Finham (South)	*1974*	*No significant problems*	*Not yet*	*Good, only have had to repair several small line leaks*
Hartshill	*1973*	*No significant problems*	*Not yet*	*Fair, some slime growth*
Minworth	*1971*	*No significant problems*	*Not yet*	*Good, tanks cleaned once/year and domes brushed*
Strongford (New Plant)	*1972*	*No significant problems*	*Not yet*	*Good*
The Netherlands				
Holten-Markelo	*1978*	*No significant problems*	*Not yet*	*Good*
Steenwijk	*1977*	*No significant problems*	*Not yet*	*Good*
United States				
Glendale, Calif.	*1978*	*Several blowoff lines failed*	*Not yet*	*Good, small evidence of slime*
Madison, Wisc.	*1977*	*No significant problems*	*Not yet*	*Substantial sliming problem in mid-1980 after 3 yr of operation*
Fort Worth, Tex.	*1978*	*Some problems with blowoffs*	*Not yet*	*Some line breaks and problems evident, but overall performance stable*
Tallman Island, N.Y.	*1979*	*No significant problems*	*Not yet*	*Good*

**Initially. Cleaning has not been required for the last 6 yr.*

To summarize, slime growths appeared to occur in zones of heavy organic loading, or low D.O., or both. The occurrence of these growths was exacerbated by extreme plug flow aeration tank design and the presence of strong industrial wastes.

Conclusions

In general, dome diffuser fine bubble aeration systems were providing relatively efficient, low-maintenance service in the surveyed plants. However, the plant visits and related study clearly indicated a need for optimized design and operating control strategies if the full energy saving potential of the equipment is to be realized. Listed below are the principal conclusions resulting from this study:

1. Assessment of data from the surveyed plants resulted in widely varying estimates of field oxygen transfer performance for the dome diffuser. Generally, field performance was lower than might be expected from clean water oxygen transfer data. With the use of a mass balance technique (based on empirically derived oxygen consumption values for BOD_5 removed and ammonia nitrogen oxidized and a similarly derived oxygen credit for nitrate nitrogen denitrified), the process (i.e., dirty water or mixed liquor) aeration efficiency for the 16 of 19 plants with adequate data to make predictive estimates averaged 1.48 kg O_2 transferred/kWh consumed (2.43 lb O_2/wire hp-hr). The highest and lowest observed aeration efficiencies were 2.13 kg O_2/kWh (3.50 lb O_2/wire hp-hr) and 0.78 kg O_2/kWh (1.28 lb O_2/wire hp-hr) at Oxford and Steenwijk, respectively. For the three plants (Finham, Madison, and Glendale) with a reasonably sufficient comparative data base, fine bubble dome diffuser process aeration efficiency was approximately 1.65 times higher than for side-by-side coarse bubble diffuser systems: 1.56 kg O_2/kWh (2.56 lb O_2/wire hp-hr) vs. 0.95 kg O_2/kWh (1.56 lb O_2/wire hp-hr).
2. Methods of plant operation frequently contributed to less-than-optimum oxygen transfer performance.
    - In the U.K. plants particularly, volumetric and F/M loading rates were often lower than required for nitrification, or high levels of BOD removal, or both. The least energy efficient plants, with two exceptions, were underloaded volumetrically.
    - A number of the plants were also overaerating the mixed liquor and had taken no steps to monitor D.O. concentrations and reduce air flows to more efficient operating levels. The two most energy efficient plants, Oxford and Beckton, closely monitored mixed liquor D.O. and adjusted air flows accordingly.
3. Lowered oxygen transfer efficiency could also be traced to design practices that make it very

difficult for operators to run treatment plants effectively.

- When multiple-pass plug flow systems are used, the air supply capability is poorly matched with the oxygen demand, particularly in the second and subsequent aeration channels. This leads to overaeration in the latter passes and localized organic overloading and diffuser sliming in the first pass. Step feeding only partially alleviated the overaeration problem. Tapering the aeration dome configuration was also of limited value in suppressing overaeration in the second and subsequent passes of multiple-pass systems; however the tapering significantly helped suppress diffuser sliming. In terms of overall oxygen transfer performance, tapered aeration apparently had no apparent advantage over the nontapered systems.
- The full practical operating range attainable with the equipment, in terms of air flow per dome, is not properly used in selecting diffuser density. Providing too many domes creates a situation where the minimum total aeration system air flow is controlled by the minimum allowable air flow rate per dome (0.014 m^3/min or 0.5 cfm, defined by control orifice headloss characteristics) for large portions of the day; this produces extended periods of overaeration. The recommended maximum unit dome air flow rate of 0.057 m^3/min (2.0 cfm) is consequently rarely approached in operation.
- Many of the plants had shallow aeration tanks, 3.7 m (12 ft) or less, which reduces attainable oxygen transfer efficiency.
- Most of the plants lacked air flow monitoring capability for individual aeration grids, and air control valves, where provided, were usually too coarse in their adjustability to be of use in controlling air flows. Plant operators were often prevented from correcting overaeration conditions because of equipment limitations.

4. Significant industrial waste fractions in municipal wastewater may substantially lower dome diffuser oxygenation efficiency via a reduction in the alpha factor. Alpha is especially affected in the first segment of long, plug flow aeration tanks (to values reportedly as low as 0.3 to 0.4) where detergents and other surfactants haven't had sufficient contact time to be biodegraded. As these surfactants are oxidized in passing through the aeration process, alpha reportedly increases to values of 0.8 or higher at the effluent end of the tank. Beddington and Hartshill are two examples of plants that are adversely affected by industrial waste discharges.
5. The authors believe that, with enhanced design and operating techniques, aeration efficiencies of dome diffuser plants with no unusual alpha depressing wastes present could be increased 25 to 75 percent over the average value of 1.48 kg O_2 transferred/kWh (2.43 lb O_2/wire hp-hr) estimated from the survey.
6. The limited data evaluated in this study indicate some parity of performance among the ceramic dome and disc diffusers presently being marketed in the United States. There appears to be a definite correlation between dome or disc diameter (of the horizontal surface) and specific oxygen transfer per diffuser. Data from clean water tests suggest that fewer of the larger diameter units may be required to transfer equivalent amounts of oxygen at the same oxygen transfer efficiency.
7. Generally, maintenance experience with dome diffusers ranged from good to excellent. Both of the plants reporting significant maintenance problems, Beddington and Basingstoke, had developed operating strategies that were effectively controlling the problems without excessive costs or downtime. It is concluded that the generally quite good maintenance experience is directly attributable to two principal factors:
    - Conscientious (though not labor intensive) attention to aeration system operation, particularly that relating to air cleaning and repair of infrequent equipment failures.
    - Steady improvement and refinement of the dome diffuser equipment and its application over the course of its history, particularly in piping and air cleaning.
8. Diffuser sliming, causing external fouling, is apparently produced by conditions of high F/M loading, or low D.O., or both—conditions that can occur when strong industrial wastes are introduced into a plant. Three plants, Beckton (temporary reduction of loading), Beddington (brushing), and Madison (steam cleaning) have developed somewhat effective responses to sliming.
9. In designing new plants, close attention should be given to required air flow at minimum loading. Use of a wider range of air flows in the design of dome diffuser systems, as now recommended by the manufacturer, will improve operational flexibility and thereby improve overall system efficiency. Aeration efficiency is only one parameter of diffuser performance; high reliability and flexibility of operation should also be considered in conjunction with operational and capital costs.
10. Careful attention should be given to air cleaning to avoid internal fouling of dome diffusers. Manufacturer's recommendations in this area should be followed carefully. When dome diffuser systems are retrofitted into existing plants, existing air piping should be carefully checked for rusting or scaling and should be cleaned or coated as needed to avoid particle shedding from the pipe walls into the air stream where it can cause internal diffuser fouling.

Recommendations

This study has identified a number of significant research needs that should be addressed as soon as practicable:

1. The question of alpha sensitivity as it relates to the relative performance under field operating conditions of dome/disc diffusers versus other aeration devices should be a high priority research need.
2. The opportunity to develop useful side-by-side comparison data for dome diffusers, coarse bubble aerators, and fine bubble tube diffusers (in wide band spiral flow) exists at three U.S. treatment plants: Madison, Wisconsin; Tallman Island (New York City); and Fort Worth, Texas. In conjunction with ongoing process (dirty water) testing at the Los Angeles County Sanitation Districts, data should be developed from these plants.
3. Oxygenation performance studies of plants that have been modified to optimize application of dome or disc diffusers should be conducted as soon as possible. Such studies could possibly be rapidly implemented in cooperation with the WRC. In addition, one or more major tests in U.S. plants should be initiated in the near future, possibly under EPA's Innovative Technology Program.
4. The Nokia and Degremont diffusers, which have experienced significant overseas application, are now being marketed in the United States. A follow-up effort to evaluate the O&M performance of this equipment is recommended. The Nokia dome, in particular, represents a radical departure from conventional ceramic dome technology and should be of prime interest in further studies.
5. Data evaluated during this project appear to predict substantial performance equivalence between the Norton/Hawker-Siddely dome, the Sanitaire disc, the Degremont disc, and the Nokia disc. The larger diameter Sanitaire and Degremont units may transfer more oxygen per diffuser, allowing the use of fewer diffusers, when compared with the smaller Norton/Hawker-Siddely dome. Available data are too limited for final judgment, however, and further evaluation is strongly recommended.
6. Diffuser cleaning is a labor intensive and costly process that can usually be forestalled by careful O&M. Providing for diffuser cleaning was the usual practice in the United Kingdom, however, and appears prudent in light of British experience. Alternatives to refiring, notably ultrasonic cleaning, need further development. Further study of ultrasonic cleaning might be carried out in cooperation with the Fort Worth, Texas, plant to document labor requirements, cleaning effectiveness, and equipment reliability.

These recommendations have been stated in terms of urgency. In view of the increasing number of dome and disc diffuser systems being designed and bid in the United States, it is believed that expedited research is necessary to avoid repeating the deficiencies observed at the surveyed plants.

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The complete report, entitled "Survey and Evaluation of Fine Bubble Dome Diffuser Aeration Equipment," (Order No. PB 82-105 578; Cost: $15.50, subject to change) will be available only from:

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